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DOCUMENT CONTROL ADMINISTRATOR

INSTRUCTION BOOK

MODEL 74C-S21

20KC CAPACITANCE BRIDGE

Serial # 537

323504 G3 S7

The Model 74C-S21 is the same as the standard Model 74C except that its operating frequency is 20KC.

Boonton *ELECTRONICS* Corporation

738 SPEEDWELL AVENUE, MORRIS PLAINS, NEW JERSEY, U. S. A.

SECTION 12

TABLE OF REPLACEMENT PARTS

FOR

CAPACITANCE BRIDGE

MODEL 74C-S21

NOTE:

Components in the "bridge" section have not been included, since in general their replacement must be followed by adjustments that require specialized equipment and techniques.

Reference	Description	BEC Part Number
C1 Capacitor	.035 µf ± 1% 500V	Special
C2 " (not used)		
C3 "	0.05 µf 400V	230,110
C4 "	0.05 µf 400V	230,110
C21 "	0.01 µf 400V	230,111
C23 "	5 µf 6V	283,108
C25 "	0.01 µf 400V	230,111
C27 "	0.05 µf 400V	230,110
C29 "	0.01 µf 400V	230,111
C31 "	5 µf 6V	283,108
C32 "	0.01 µf 400V	230,111
C33 "	400 pf 5% 500V	201,148
C34 "	0.047 µf 500V	236,002
C35a "	20 µf 450V	P/O 283,100
C35b "	20 µf 450V	P/O 283,100
C36 "	0.1 µf 200V	230,136
C37 "	0.047 µf 500V	236,002

Reference	Description	BEC Part Number
D1 Diode	IN58AS	530,021
F1 Fuse	AGC 0.5 Amp.	545,502
F2 Fuse	AGC 0.5 Amp.	545,502
L1 Choke 7hy	Stancor C1707	440,001
M1 Meter, 200µa	M-Honeywell MM2	554,116
PL-1 Bulb	#47	545,101
R1 Resistor	220K Ω 1/2W 10%	301,143
R2 "	2.2K Ω 1/2W 10%	301,015
R3 "	2.2K Ω 1/2W 10%	301,015
R15 "	470K Ω 1/2W 5%	301,029
R16 "	1Meg.Ω 1W 20%	302,128
R17 "	100 Ω 1/2W 5%	301,063
R18 " Var.	10K Ω 2W 10%	311,124
R19 "	4.7K Ω 1/2W 5%	301,103
R20 "	470K Ω 1/2W 10%	301,029
R21 "	470K Ω 1/2W 10%	301,029
R22 "	100 Ω 1/2W 5%	301,063
R23 "	4.7K Ω 1/2W 5%	301,103
R24 "	68K Ω 1/2W 10%	301,024
R25 "	7.5K Ω 10W 10%	312,100
R26 "	27K Ω 1W 5%	302,135
R27 "	470 Ω 1/2W 5%	301,079
R28 "	47K Ω 1W 5%	302,141
R29 " Var.	50K Ω 2W 10% (Linear)	311,125

Reference	Description	BEC Part Number
S1 Switch, Toggle DPST	Carling #216-62	465,100
S6 Switch, Toggle DPST	AH & H 81027AZ	465,101
T1 Oscillator Coil	Special	074,031
T4 Transformer, Input	Special	074,032
T5 Transformer, I.F.	Special	074,033
T6 Transformer, Output	Special	074,034
T7 Transformer, Power	Stancor PC 8401	446,007
TS-1 Terminal Shield		074,022
V1 Tube	6C4	526,6C4
V2 Tube	6AH6	526,6AH6
V3 Tube	6AH6	526,6AH6
V4 Tube	6X4	526,6X4
V5 Tube	OA2	526,OA2

74C CAPACITANCE BRIDGE

INSTRUCTION BOOK

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SECTION I

SPECIFICATIONS

Capacitance Range	.0002 pf to 11,000 pf
Conductance Range	.001 micromho to 1,000 micromhos
Resistance Range	1,000 Ω to 1,000 megohms
Direct-Capacitance Accuracy	±(0.25%) + Range Factor*
Grounded-Capacitance Accuracy	±(0.25% + 0.5 pf)
Conductance Accuracy	± 10% + Range Factor*
Resistance Accuracy	± 10% + Range Factor*
Frequency	100 kilocycles ± 1%
Test Signal Level	
HI-LO switch on LO	approx. 20 mv to .8v
HI-LO switch on HI	approx. .6v to 3v
Power Requirements	105-125 volts, 50-60 cy. 30 watts
Weight	22 pounds
Size	Width 14", Height 11" Depth 8 1/2"
Tubes	1-6X4, 1-OA2, 2-6AU6, 1-6C4

*See Section IV, page 4

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SECTION II

GENERAL DESCRIPTION

The Model 74C Three-Terminal Capacitance Bridge was designed to provide the industry with a compact self-contained precision instrument for measuring capacitance and conductance. Measurements may be made of either direct-capacitance or grounded-capacitance.

When measuring direct-capacitance, stray or test cable capacitances to ground do not affect the measurement, and small values of capacitance may be measured easily and accurately.

The wide range of capacitance and conductance measurements possible, 0.0002 pf to 11,000 pf and 0.001 to 1,000 micromhos, is obtained without auxiliary equipment. Below 1000 pf, the capacitance and conductance of the test are both read directly from their respective dials. See note at foot of Section IV, "Range and Accuracy".

SECTION III

DIRECT-CAPACITANCE VS. GROUNDED-CAPACITANCE

Direct-capacitance is the capacitance existing between two conducting elements, excluding all stray capacitance that may exist by way of a third or fourth, etc. conducting element.

Typical examples of direct-capacitance measurement applications are the following:

1. Capacitance between control grid and plate of vacuum tubes, excluding capacitance to cathode, screen grid, or suppressor.
2. Capacitance between any two conductors in a cable, excluding capacitance to all other conductors or shield.
3. Capacitance between any two conductors of a printed circuit, excluding capacitance to all other conductors.
4. Capacitance between any two windings of a transformer, excluding capacitance to all other windings or shields.

Grounded-capacitance is the capacitance existing between two conducting elements when one element is grounded, and includes all stray capacitance from the high element to ground, either directly or by way of adjacent elements. For this reason, a grounded-capacitance reading will always be greater than a direct one, and will depend somewhat on proximity of chassis and adjacent components, and on measuring technique.

RANGE AND ACCURACY DETAILS

CAPACITANCE RANGES:

Multiplier	Cap. Range	Accuracy Direct*	Accuracy Grounded*
1.0	100 to 11,000 pf	±(0.25% + 0.2 pf)	±(0.25% + 0.5 pf)
.1	10 to 100 pf	±(0.25% + 0.02 pf)	±(0.25% + 0.5 pf)
.01	1 to 10 pf	±(0.25% + 0.005 pf)	±(0.25% + 0.5 pf)
.001	0.05 to 1 pf	±(0.25% + 0.001 pf)	not recommended
.001	0 to 0.05 pf	±(2% + 0.0002 pf)	" "

CONDUCTANCE RANGES:

Divider	Cond. Range	Accuracy**
1	100 to 1000 µmhos	±(10% + 10 µmhos)
10	10 to 100 µmhos	±(10% + 1 µmho)
100	1 to 10 µmhos	±(10% + 0.1 µmho)
1K	0.1 to 1 µmho	±(10% + 0.01 µmho)
10K	0 to 0.1 µmho	±(10% + 0.001 µmho)

RESISTANCE RANGES:

Multiplier	Resistance Range	Accuracy**
1	1K to 10K ohms	$\pm\left(10\% + \frac{R}{10^3}\ \%\right)$
10	10K to 100 K ohms	$\pm\left(10\% + \frac{R}{10^4}\ \%\right)$
100	100K to 1 megohm	$\pm\left(10\% + \frac{R}{10^5}\ \%\right)$
1K	1 megohm to 10 megohms	$\pm\left(10\% + \frac{R}{10^6}\ \%\right)$
10K	10 megohms up	$\pm\left(10\% + \frac{R}{10^7}\ \%\right)$

(Where R is resistance of the test in ohms)

NOTES:

* This accuracy depends largely upon measuring techniques employed. See Section VII of this manual.

** Specified CONDUCTANCE and RESISTANCE accuracies apply only below 1000 pf and when the test is connected directly to the HI and LO TEST binding posts.

SECTION V

OPERATING PROCEDURE FOR DIRECT OR GROUNDED MEASUREMENTS AT THE "HI" AND "LO" "TEST" BIND. POSTS

5.1 SET-UP AND ZERO BALANCING

1. Turn on power. For best stability the bridge should be left "on" continuously. Warm-up time for stability is approximately five hours. Switch to direct or grounded method of measurement as desired (See Section III for definitions of each).
2. Set conductance range selector switch (marked DIVIDE G/ MULTIPLY R) to 1K.
3. Set the MULTIPLY CAPACITANCE switch to position indicated in Table I, and the ADD CAPACITANCE switch to 0.

TABLE I

Capacitance to be Measured	MULTIPLY CAPACITANCE Control Setting	ADD CAPACITANCE Control Setting
1000 to 11,000 pf	1	1K thru 10K
100 to 1,000 pf	1	0
10 to 100 pf	.1	0
1 to 10 pf	.01	0
0 to 1 pf	.001	0

4. Set the CONDUCTANCE dial to zero.
5. Set the CAPACITANCE dial to zero. (Both vernier and counter dials should read zero).

6. Adjust zero balance controls (located directly above the CAPACITANCE and CONDUCTANCE dials) until the NULL INDICATOR meter reads zero. FINE capacitance zero control should be set with pointer straight up before adjusting COARSE control. SENSITIVITY control should be set to approximately mid-position. Too high a sensitivity control setting will result in unnecessary difficulty in obtaining a null indication. Too low a setting will result in reduced resolution and measuring accuracy.

7. If capacitance values above 1000 pf are to be measured, the ADD CAPACITANCE switch should now be set to the required range.

8. Connect the test capacitor to the HI and LO TEST posts. See Section VII "MEASURING TECHNIQUES" for suggested connection procedures.

5.2 MEASURING

1. Adjust CAPACITANCE and CONDUCTANCE dials until meter indicates best null. If difficulty is experienced in obtaining a satisfactory null, adjust the SENSITIVITY control accordingly. For best accuracy the null should obtain between 100 and 1000 on both the CAPACITANCE and CONDUCTANCE dials. If it appears above or below these points, the next indicated MULTIPLY CAPACITANCE and/or DIVIDE G/MULTIPLY R range should be used.

NOTE: Whenever the capacitance or conductance ranges are changed the capacitor to be measured must be disconnected and the bridge zero balanced as detailed in Section V 5.1. On the X1 conductance range it is necessary to use the main CONDUCTANCE dial to obtain zero balance due to the limited range of the conductance zero control. Conductance balance should be obtained within $\pm$ 1 small division on the G scale. This amount of dial offset does not cause significant error in the conductance readings.

5.3 INTERPRETING READINGS

1. Capacitance

After balancing capacitance and conductance to a satisfactory degree of precision, the capacitance of the test is determined directly from the CAPACITANCE dial reading, multiplied by the decimal factor indicated on the MULTIPLY CAPACITANCE dial. Capacitance values above 1000 pf are determined by adding the reading of the CAPACITANCE dial to the reading of the ADD CAPACITANCE control.

2. Conductance

For values below 1000 pf*, the conductance of the test (at 100 KC) is determined by dividing the reading indicated on the G scale of the CONDUCTANCE dial by the factor indicated on the DIVIDE G/MULTIPLY R dial.

3. Resistance

For values below 1000 pf*, the equivalent shunt resistance (at 100 KC) is determined by multiplying the reading indicated on the R scale by the factor shown on the DIVIDE G/MULTIPLY R dial.

* When measuring high Q capacitors above 1000 pf, conductance and equivalent shunt resistance readings should not be used without special correction. The readings actually represent the difference in conductance/shunt resistance between the test capacitor and the capacitors of the ADD CAPACITANCE network that are in the circuit for the measurement. Reasonable accuracy for conductance or equivalent shunt resistance obtains for test capacitors having Q's of less than about 200, however, and the CONDUCTANCE dial may be read directly for such test capacitors.

4. The Q and Dissipation Factor (D) of the test capacitor at 100 KC may be computed from the following formulae:

$$Q = 0.628C/G \qquad D = 1/Q$$

Where:
C is capacitance in pf
G is conductance in micromhos

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SECTION VI

REMOTE MEASUREMENTS (DIRECT only)

6.1 GENERAL

When certain limitations are kept in mind, remote measurements of capacitance may be made as easily, and in general, more accurately than those at the binding posts.

The use of reasonable lengths (up to 6 feet or so) of RG-58/U coaxial cable produces a small capacitance zero offset that is readily eliminated when zero balancing.

For values of test capacitance above about 1000 pf, the inductance of long coaxial cables results in an increase in capacitance and conductance readings that cannot be eliminated by zero balancing. The increase in capacitance reading is approximately + .008%/1000 pf of test capacitance/foot of extension of test cable (length of one cable). Conductance readings show errors that are roughly proportional to the length of cable, and approximately proportional to the square of the size of test capacitor.

See Table II below for selected examples.

TABLE II

Increase in Capacitance Reading due to Inductance Of Remote Coaxial Cables (RG-58/U only)

Capacitance Value Being Measured (pf)	Increase in Capacitance Reading			
	For 1 Ft. Cables		For 6 Ft. Cables	
	%	pf	%	pf
1,000	0.008	0.08	0.048	0.48
5,000	0.04	2	0.24	12
10,000	0.08	8	0.48	48

6.2 SET-UP AND ZERO BALANCING

1. Turn on power. For best stability the bridge should be left "on" continuously. Warm-up time for stability is approximately five hours. Switch to DIRECT.
2. Set the DIVIDE G/MULTIPLY R switch to 1K.
3. Set the MULTIPLY CAPACITANCE and ADD CAPACITANCE switches to positions indicated in Table I, Page 5.
4. Set the CONDUCTANCE and CAPACITANCE dials to zero.
5. Connect the coaxial cables to the HI and LO REMOTE TEST jacks on the bridge, and the center conductor of the LO coaxial cable to one terminal of the test capacitor (preferably, which has the larger capacitance to ground if this is known). Connect the braid of the coaxial cables together at the test end, and to the shield around the test capacitor (if used). (See Figure A-1 in APPENDIX A for recommended connections and procedure).
6. Adjust zero balance controls (located directly above the CAPACITANCE and CONDUCTANCE dials) until the NULL INDICATOR meter reads zero. FINE capacitance zero control should be set with pointer straight up before adjusting COARSE control. SENSITIVITY control should be set to approximately mid-position. Too high a SENSITIVITY control setting will result in unnecessary difficulty in obtaining a null indication. Too low a setting will result in reduced resolution and measuring accuracy.
7. Connect the center conductor of the HI coaxial cable to the other terminal of the test.

6.3 MEASURING AND INTERPRETING READINGS

Procedure is identical to that for tests at the HI and LO TEST binding posts. (See Section V, 5.2 and 5.3).

SECTION VII

MEASURING TECHNIQUES (See also Appendix A)

7.1 GENERAL

Direct-capacitance measurements can be made to a higher degree of accuracy than grounded measurements, particularly when the test capacitance is small (less than 100 pf) and when long test leads are necessary. Use of the direct method also reduces hand capacitance effects as well as the test capacitor position error.

When direct-capacitance measurements are made at the end of coaxial cables, the cables may be bent, twisted, moved and subjected to wide temperature variations without affecting test accuracy.

Much of the accuracy of capacitance measurements depends on the technique of connecting the test capacitor to the bridge. For example, when measuring the grounded-capacitance of a 10 pf mica capacitor the variation due to connection technique may be as much as 1 pf.

7.2 DIRECT-CAPACITANCE MEASUREMENTS

Whether measurements are being made at the TEST posts, or at the end of remote cables connected to the REMOTE TEST coaxial jacks, the test capacitor should be connected with leads as short as possible.

In many cases it may be convenient to connect the test capacitor by inserting its wire leads directly into the center conductor of the HI and LO coaxial TEST jacks. This has the advantage that the outer shell of each jack shields the leads from each other for much of their length.

If maximum accuracy is required, it is usually best to use a test fixture to keep the capacitance between the leads of the test capacitor from influencing the measurement.

All other conductors in the immediate vicinity of the elements under test must be connected to ground.

7.3 GROUNDED-CAPACITANCE MEASUREMENTS

Grounded-capacitance measurements are inherently less accurate than direct-capacitance measurements owing to unavoidable stray capacitance variations between the HI test lead and ground.

Although these variations may amount to 1 pf or more, it is usually possible to reduce this uncertainty to less than 0.5 pf by using the following procedure when preparing a test specimen:

1. Connect the ground side of the test capacitor to the LO binding post using a short length of wire.
2. Connect a short length of bare tinned copper wire to the HI binding post. Bend this wire so it approaches the test sample perpendicularly and is spaced away from all surrounding objects as much as possible. The free end should be spaced approximately 1/4 inch from the high terminal of the sample for bridge zero balance adjustments. The final measurement is made with this wire connected to the test specimen.

Contact fixtures may be used for production testing, provided their residual capacitance does not exceed the range of the COARSE and FINE controls (approx. 10 pf).

SECTION VIII

MAINTENANCE

8.1 GENERAL

The capacitance bridge has been carefully calibrated at the factory against three-terminal capacitance standards certified by the National Bureau of Standards. Unless comparable standards are used, re-calibration of this instrument by other than the manufacturer is inadvisable.

8.2 REMOVING FROM THE CABINET

Remove the two screws holding the chassis to the bottom of the cabinet and the four screws at the outer edges of the panel. Remove Binding Post Jack Assembly from top of cabinet. The instrument may now be eased out of the cabinet.

8.3 CHECKING TUBES

Tubes may be checked on any good tube checker, and replaced if found to be poor. No tube selection is necessary. Access to the 100 KC oscillator (6C4) tube is gained by removing the two screws holding the shield can (marked "6C4") located underneath the main chassis. Care should be taken when replacing the shield can to see that the wires entering the slots are not trapped and pinched.

8.4 VOLTAGE CHECKS

As an aid in trouble shooting, the following table gives normal voltages at significant test points.

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TABLE III

Conditions:

Line input 115V, 60 cycles.

Bridge balanced at zero.

Use 20,000 ohms/volt or VTVM for DC measurements.

Use VTVM (such as Ballantine 300) for 60 cycle and 100 KC AC measurements.

Test Point		Normal Range of Readings
Pin 7	6X4	250 - 300V DC
Pin 1,5	OA2	145 - 155V DC
Pin 4	6C4	210 - 260V DC
J4	(osc. output)	1V, RMS (100 KC) (with coax. cable off)
Pin 5	6AU6's	230 - 280V DC
Pin 6	6AU6's	130 - 150V DC
Pin 4	6X4	6.0 - 6.6V RMS (60 cy)

NOTE:
All voltage tests to ground.

8.5 CONDUCTANCE TESTS

1. To check the operation of the conductance measuring circuit, first set the DIVIDE G/MULTIPLY R switch at "1", the MULTIPLY CAPACITANCE switch at "1", and the CAPACITANCE dial at "0".

Then balance the bridge using the COARSE and FINE capacitance controls and the CONDUCTANCE dial. The conductance zero set control (located directly above the CONDUCTANCE dial) should have the pointer straight up.

Balance should be reached with the CONDUCTANCE dial at or near zero (within ± 10 micromhos).

2. With the CONDUCTANCE dial left at the setting that gave balance on the "1" range, it should be possible to achieve a conductance balance on the other DIVIDE G/ MULTIPLY R ranges in either DIRECT or GROUNDED positions of the GROUNDED-DIRECT switch, using only the conductance zero control and the COARSE and FINE capacitance zero controls.

3. A quick test of operation on all DIVIDE G/MULTIPLY R ranges may be performed using 1% deposited-carbon resistors of 1K, 10K, 100K, 1 megohm, and 10 megohms.

a. First, set up as in step 1. Then connect the 1K resistor to the HI and LO TEST posts, and balance the Bridge using the CONDUCTANCE and CAPACITANCE dials. Read the indicated value on the CONDUCTANCE dial.

b. Remove the resistor, switch to "10" on the DIVIDE G/MULTIPLY R control, and re-balance using the conductance zero control and the COARSE and FINE capacitance controls. Connect the 10K resistor and again balance using the CONDUCTANCE and CAPACITANCE dials. Read the indicated resistance value on the CONDUCTANCE dial and multiply by 10.

c. Repeat the procedure of step b. on the "100" range, the "1K" range, and the "10K" range using the 100K, 1 megohm, and 10 megohm resistors respectively. In each case readings should fall within ± 11% of full scale on the CONDUCTANCE dial. (See "Resistance Accuracy" specifications of Section IV, RANGE and ACCURACY).

8.6 100 KC OSCILLATOR AND AMPLIFIER CHECK AND ADJUSTMENT

1. Unless the 100 KC oscillator tuning (OSC ADJ) control has been re-set, or the 100 KC IF transformer (T4, T5, T6) adjustments disturbed, no adjustment of these tuned circuits should be required. If it is necessary that the operating frequency be exactly 100 KC, a counter or frequency meter may be connected to the LO and GND TEST binding posts (bridge set for DIRECT, and with the rear-of-chassis oscillator level controls set for maximum). Use OSC ADJ (near J4) to set the frequency, then peak the IF and check for over-all operations as in step 2.

2. To check for satisfactory operation of the 100 KC circuits, set the GROUNDED-DIRECT switch to DIRECT, the DIVIDE G/MULTIPLY R switch on "1K" the MULTIPLY CAPACITANCE control to ".001" and the SENSITIVITY control full on. Turn the CAPACITANCE dial to zero and balance the bridge.

   Turning the CAPACITANCE dial 1 pf (effective change is 1 x 0.001, or 0.001 pf) in either direction from balance should produce a change in meter reading of at least 25 microamperes.

3. If a change of less than 25 microamperes is observed it is possible that the 100 KC oscillator is not properly set to the IF frequency. To check this, disconnect the coax cable from J3, and with the SENSITIVITY control at maximum carefully set OSC ADJ for highest meter reading. Re-connect to J3 and repeat step 2 to determine whether or not satisfactory sensitivity has been achieved.

4. If sensitivity is still inadequate, again remove the connector from J3 and peak the trimmers of T4, T5 and T6 for maximum meter reading. (There will be sufficient pick-up of the 100 KC oscillator to serve as the peaking signal input).

8.7 CHECK OF CAPACITANCE ACCURACY ON "1" RANGE MULTIPLY CAPACITANCE SWITCH

The variable capacitor has been very accurately adjusted at the factory to insure tracking with the CAPACITANCE dial calibration. The accuracy at the 1000 pf point may be determined as follows:

1. Balance the bridge with the CAPACITANCE and CONDUCTANCE dials at 0 and the GROUNDED-DIRECT switch on DIRECT. After balancing, set the ADD CAPACITANCE switch on "1K". Connect an adjustable capacitor (preferably made up of fixed silver mica units padded with a small air variable, and contained in a shielded case) between the HI and LO TEST posts of the bridge, with the case to the GND post. Re-balance the bridge by varying the external capacitor and the CONDUCTANCE dial.

2. Turn the ADD CAPACITANCE switch to "0". Re-balance the bridge using the CAPACITANCE and CONDUCTANCE dials. The CAPACITANCE dial should read 1000 $\pm$ 1.5 pf.

8.8 CHECK OF OTHER RANGES

If the preceding check of the 1000 pf point has shown good agreement, it is reasonably certain that the calibration can be relied on over the entire dial. If desired, however, it may be checked by the step-up method. Similarly the accuracy of each of the other ranges may be determined by transfer downward (for example the exact dial reading for 100 pf on the "1" range may be determined by step-up, then the external air variable adjusted for bridge balance at that reading and used to check full scale on "0.1" range).

Direct-capacitance (three terminal) standards (Model CS-), for use in checking the calibration of the bridge can be supplied on order at any requested value between 0.01 pf and 1000 pf.

SECTION IX

APPLICATIONS

9.1 DIFFERENTIAL MEASUREMENTS

1. Description

The bridge may be used to measure very small capacitance differences between fairly large capacitors, hence, measurements of very small temperature coefficients can be made. The use of the direct method of measurement avoids errors resulting from stray or variable capacitance to ground.

2. Operating Procedure for Differential Measurements

a. Switch to DIRECT. Plug the accessory board into the banana jacks (beneath the port cover) on top of the cabinet.

b. Set the CAPACITANCE dial at mid-scale (500 pf). Select a MULTIPLY CAPACITANCE switch position that will give a suitable range of capacitance. Either the ".01" or ".001" range may be required, depending on the range of expected differential capacitance.

c. Balance the bridge, using the COARSE and FINE capacitance controls and the conductance zero.

d. Connect the reference capacitor to the front two terminals of the accessory board (on top of the cabinet), and the test capacitor to the HI and LO TEST posts on the front of the Bridge.

e. Adjust the CAPACITANCE and CONDUCTANCE dials of the bridge to restore balance. (The conductance reading is the difference in conductance between the reference capacitor and the test, hence should not be considered as reflecting the actual conductance of either capacitor).

f. The change in capacitance as indicated by the dial and its MULTIPLYING factor is the differential capacitance. (pf difference in CAPACITANCE dial reading from 500.0 pf, times the MULTIPLY CAPACITANCE factor used). The dial reading is direct sensing, i.e., a higher-than-500 pf reading indicates that the capacitor on the HI and LO TEST posts is higher in capacitance than the reference.

3. SUGGESTION FOR OBTAINING GREATEST ACCURACY

Additional accuracy can also be obtained by interchanging the two capacitors and re-measuring their difference. Ideally the amount of difference from 500 pf should be identical, but the readings should be in opposite directions from the 500 pf point. Errors may be minimized by averaging the two differences from 500 pf and using the average as the measure of differential.

4. TEMPERATURE COEFFICIENT MEASUREMENTS

Probably the most useful application of the differential method of measurement is in determining the temperature coefficient of capacitors.

Here the "Direct" method of measurement is invaluable, for it allows the use of flexible shielded cables between the bridge and the capacitor to be tested, without introducing errors due to cable or stray capacitance to ground. Thus, standard temperature chambers may be used without the usual elaborate access provisions.

A stable reference capacitor should be used, preferably one of low temperature coefficient to minimize the effects of room temperature variations. An Auxiliary Capacitor (Type AC-1), designed for this use, is available on order. This, plus the built-in features of the Bridge, enables measurements of the temperature coefficient of capacitors between 0 and 11,000 pf.

For temperature coefficient measurements both the Bridge and reference capacitor should be given sufficient warm-up time to stabilize (preferably at least 5 hours); or left on continuously.

No external reference capacitor is necessary when the capacitor to be tested is less than 10 pf. In this case the CAPACITANCE dial can be set to 500 pf (mid-scale) on either the ".01" or ".001" range, and the COARSE and FINE controls used to balance the Bridge (in place of a "reference" capacitor).

9.2 CAPACITANCE AND CONDUCTANCE MEASUREMENTS OF SEMICONDUCTORS

1. LOW DISTORTION OSCILLATOR

To reduce turnover* error when measuring semiconductor diodes, the 100 KC oscillator has been designed to have unusually low harmonic distortion.

*A change in capacitance or conductance reading when both diode and the bias polarity have been reversed at the test connections.

2. VARIABLE TEST SIGNAL LEVEL

Built-in means are provided for varying the level of the 100 KC test signal. A switch and potentiometer (accessible from the rear of the cabinet) allow control between a high of 3V and a useful low of approximately 20mv across the TEST posts.

An accessory fixed attenuator (Model 75-1A) may be used to reduce the level of test signal by approximately 40 db (thus producing an adjustment range from about 40 mv to below 1 mv).

3. BUILT-IN VARIABLE DC BIAS

A special model (74C-S8), incorporating an integral DC bias supply, is available for use when it is necessary to apply DC bias to a semiconductor under test.

Bias voltages are adjustable to +100V or to -5V, with a maximum current of 10 ma. The maximum bias available varies with the range setting of the DIVIDE G/MULTIPLY R switch.

R/G SWITCH RANGE	APPROXIMATE MAXIMUM DC BIAS VOLTAGE	
	+	-
10K	100	5
1K	100	5
100	90	5
10	30	4.9
1	5	4.5

APPENDIX A

Some Comparisons Between Capacitance Measurement Errors at 100 KC and 1 MC

A. General:

Use of 100 KC as the test frequency offers considerable advantage in several areas which include:

1. Measurements above 100 pf, whether remotely or at the bridge.
2. Practically all remote measurements when appreciable capacitance exists between either HI or LO TEST post and ground.
3. All measurements when the test itself is not a simple two-terminal capacitor, but has capacitance from either or both terminals of the test to other elements.

Figure A-1 shows the recommended set-up procedure for making remote measurements.

B. Errors due to Lead Inductance

Above about 100 pf the use of 100 KC as the test frequency greatly reduces the error due to the inductance of the leads connecting the bridge to the test.

Graph 1 shows the added error due to lead inductance when 1 foot long RG-58/U coaxial cables are added between the bridge and the test capacitor. It is apparent that at 100 KC this error is about 100 times less than at 1 MC.

It should be noted that Graph 1 does not give total measurement errors - only the increase in reading per foot of the specified coaxial cables. At 1 MC, the inductance of leads

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internal to the bridge can and does contribute appreciable error. (See Table V, page 18 of the 75A Instruction Book for average errors due to internal inductance).*

This error, of course, is present whether open wire leads or coaxial cable are used to connect the test to the bridge.

C. Errors due to Coaxial Cable Capacitance

Below about 50 pf the capacitance between the center conductor and outer braid of the coaxial cables causes an increase in capacitance reading. This effect is generally negligible at 100 KC, but appreciable at 1 MC. Graph 2 shows the approximate magnitude of this error. Note that the error is not a constant percent-per-foot; instead it becomes greater the longer the cables.

D. Errors due to Measuring Other Than a Simple Two-Terminal Test

Graph 3 shows representative errors when measuring a 2.2 pf ceramic capacitor in the presence of capacitance between the LO side of the test and ground (cable braid); the HI side and ground; and with equal values from both sides to ground.

* TABLE V (FROM 75A CAPACITANCE BRIDGE INSTRUCTION BOOK)

CORRECTION FOR INTERNAL INDUCTANCE: X1 CAPACITANCE RANGE ONLY

CAPACITANCE DIAL READING (pf)	50	100	200	300	400	500	600	700	800	900	1000
ADJUST READING BY ADDING: (pf)	+0.03	+0.2	+0.25	+0.05	0.0	-0.05	-0.2	-0.4	-0.7	-1.0	-1.6

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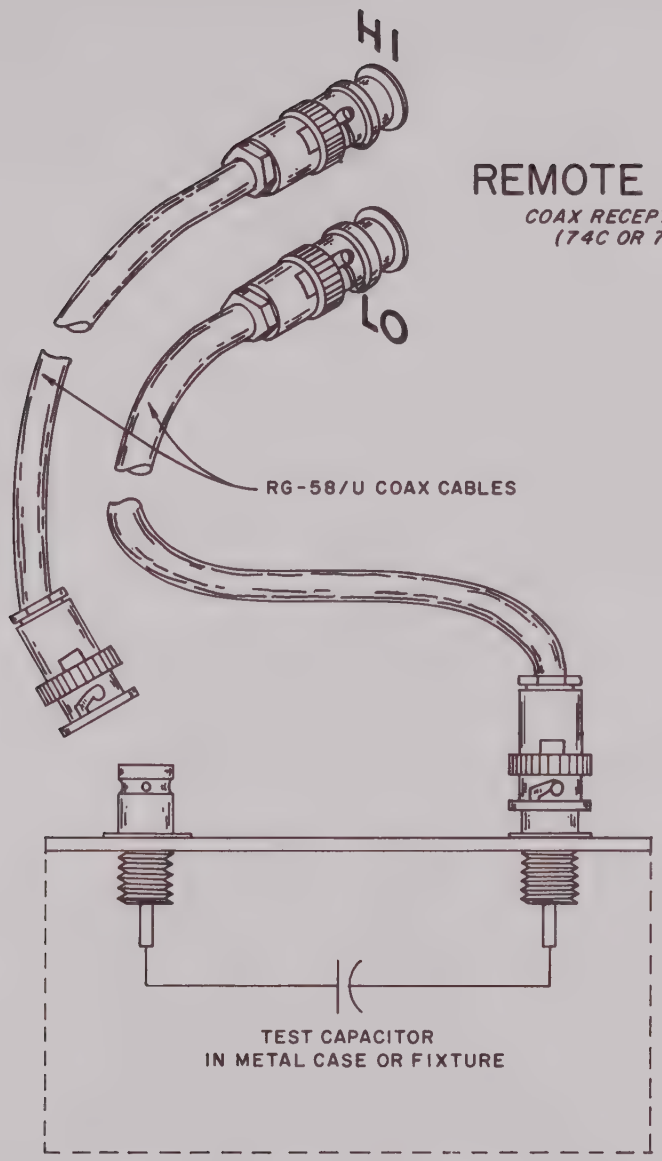


SETUP FOR REMOTE MEASUREMENT OF CAPACITORS USING COAXIAL CABLES (DIRECT ONLY)

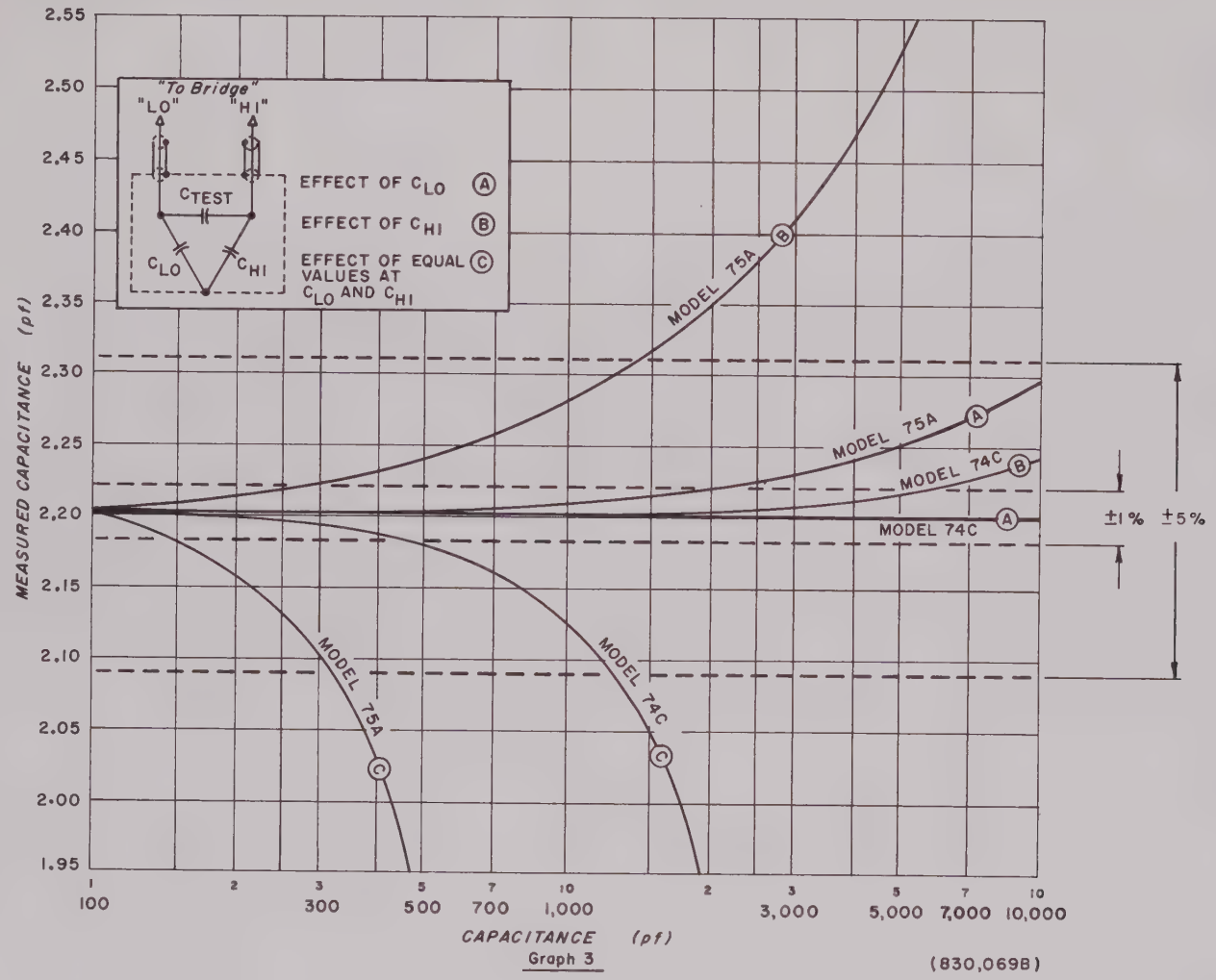
PROCEDURE:

1. *Connect both cables to the bridge, and connect the* LO *cable to the case receptacle of the test that has the greatest capacitance to case (if any).*
2. *Balance the bridge*
3. *Connect the* HI *cable to the other case receptacle and measure.*

Figure A1

(830,070A)

REPRESENTATIVE ERRORS WHEN MEASURING A 3-TERMINAL CAPACITOR

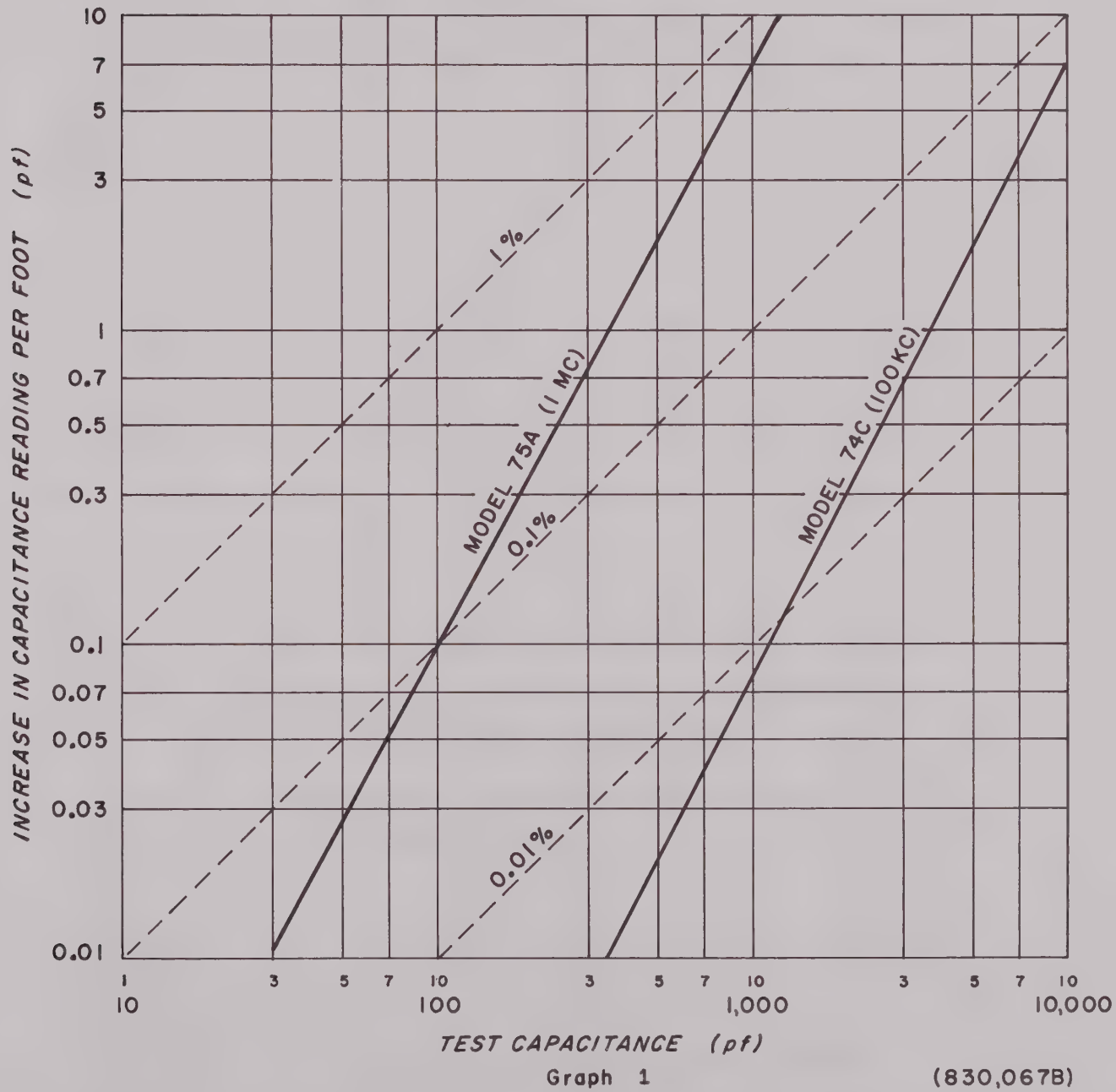


Graph 3

(830,0698)

REMOTE MEASUREMENT ERROR DUE TO CABLE INDUCTANCE

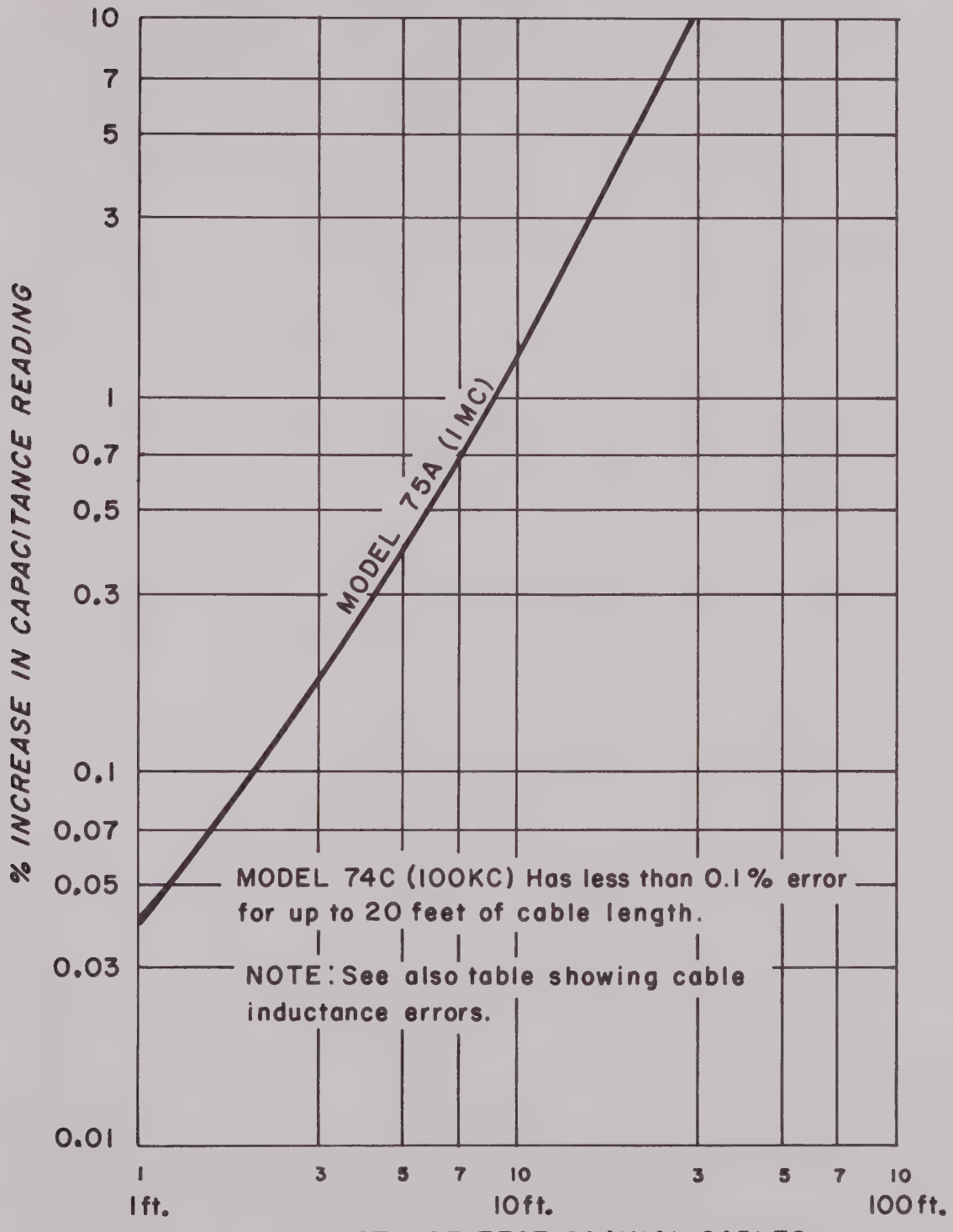
(INCREASE IN CAPACITANCE READING PER FOOT OF RG-58/U CABLES)



Graph 1

(830,067B)

REMOTE MEASUREMENT ERROR DUE TO CABLE CAPACITANCE



Graph 2 (830,068A)

SECTION X

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SECTION XI

WARRANTY

Boonton ELECTRONICS Corporation guarantees to the original purchaser that each instrument it manufacturers be free from defects in material and workmanship for a period of one year after date of initial shipment. Our liability is limited to repairing or replacing any defective part with the exception of vacuum tubes, panel lamps, fuses, choppers, and batteries. The warranty lapses if, upon our examination, we judge that the instrument has been abused in any way.

PROCEDURE TO FOLLOW WHEN INSTRUMENT IS DEFECTIVE

1. Call our plant or our representative nearest you. A simple solution may result from discussion of the problem with our trained personnel.
2. If the fault is not readily eliminated, prepare the instrument for return to us. Pack carefully in a sturdy container using several inches of shock absorbing material on all six sides of the instrument. Include all probes, cables, or accessory units. On all paper work pertaining to the returned instrument, note the model and serial number and state briefly the details of the fault. Ship to us transportation charges prepaid.
3. If the instrument is within the warranty, we will repair and return to you transportation charges prepaid. If the instrument is beyond the one year warranty period, we will repair and return it unless approval on a cost estimate is requested. If the instrument is within the one year warranty period, but our examination reveals abuse, we will await approval of our cost estimate before proceeding with repairs.

SECTION XII

TABLE OF REPLACEABLE PARTS

NOTE:

Components in the "bridge" section have not been included, since in general their replacement must be followed by adjustments that require specialized equipment and techniques.

Reference		Description	BEC Part Number
C1	Capacitor	2000 pf ± 5% 500V	200,500
C2	"	470 pf ± 2% 500V	200,501
C3	"	0.05 µf 400V	230,110
C4	"	0.05 µf 400V	230,110
C21	"	0.01 µf 400V	230,111
C23	"	5 µf 6V	283,108
C25	"	0.01 µf 400V	230,111
C27	"	0.05 µf 400V	230,110
C29	"	0.01 µf 400V	230,111
C31	"	5 µf 6V	283,108
C32	"	0.01 µf 400V	230,111
C33	"	100 pf ± 5% 500V	200,001
C34	"	0.05 µf 500V	224,109
C35a	"	20 µf 450V	P/O 283,100
C35b	"	20 µf 450V	P/O 283,100
C37	"	0.05 µf 500V	224,109
D1	Diode	IN34A	530,005
F1	Fuse	AGC 0.5 Amp.	545,502
F2	Fuse	AGC 0.5 Amp.	545,502

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Reference	Description	BEC Part Number
L1 Choke, 7hy	Stancor C1707	440,001
M1 Meter, 200μa	M-Honeywell MM2	554,116
PL-1 Bulb	#47	545,101
R1 Resistor	220K Ω 1/2W 10%	301,143
R2 "	2.2K Ω 1/2W 10%	301,015
R3 "	2.2K Ω 1/2W 10%	301,015
R15 "	470K Ω 1/2W 5%	301,029
R16 "	1 Meg 1 W 20%	302,128
R17 "	470 Ω 1/2W 10%	301,011
R18 "	10K Ω Var. 2W 10%	311,124
R19 "	10K Ω 1/2W 10%	301,019
R20 "	470K Ω 1/2W 10%	301,029
R21 "	470K Ω 1/2W 10%	301,029
R22 "	470 Ω 1/2W 10%	301,011
R23 "	10K Ω 1/2W 10%	301,019
R24 "	68K Ω 1/2W 10%	301,024
R25 "	7.5K Ω 10W 10%	312,100
R26 "	27K Ω 1W 5%	302,135
R27 "	470 Ω 1/2W 5%	301,079
R28 "	47K Ω 1W 5%	302,141
R29 "	50K Ω Var. (Linear) 2W 10%	311,125

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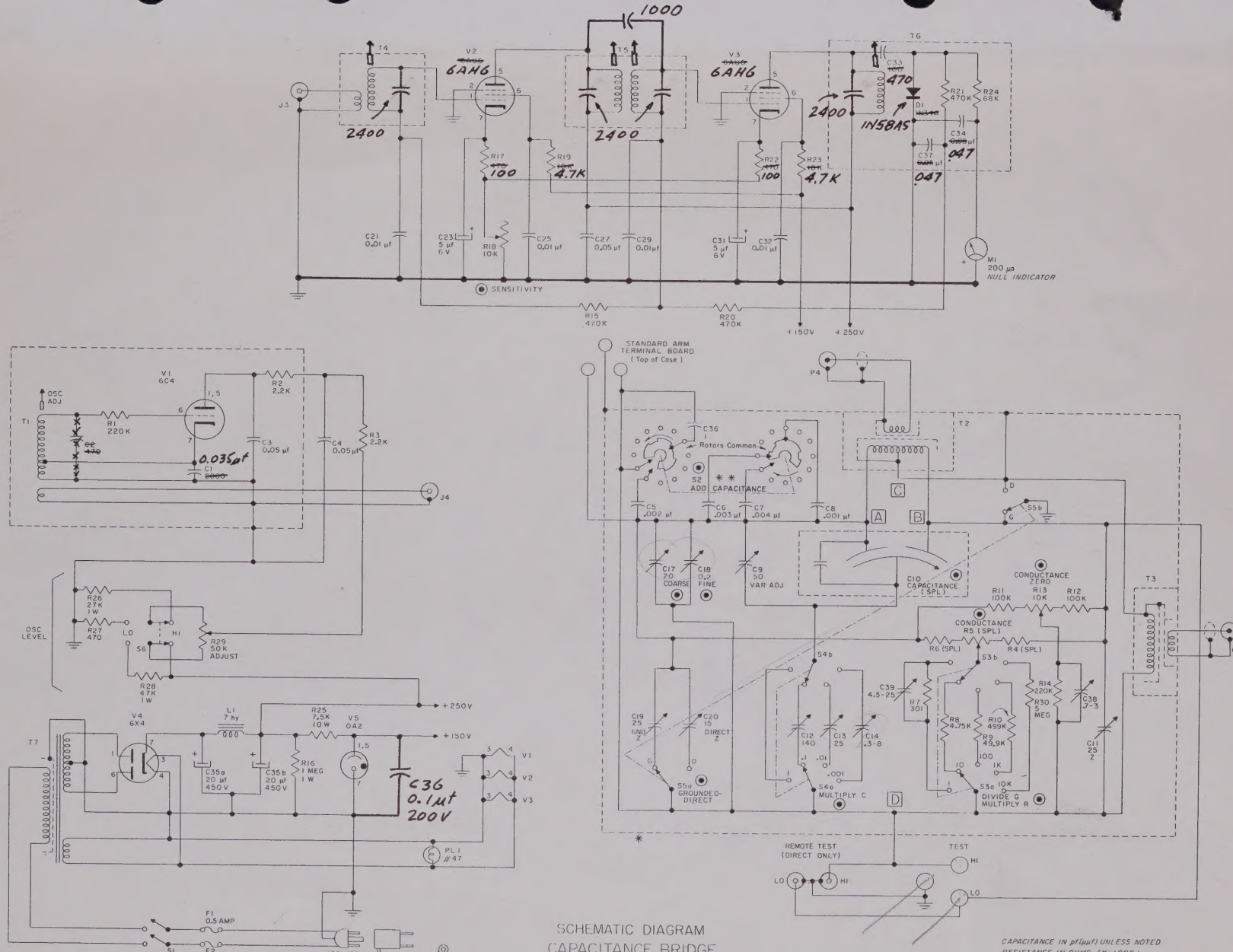
Reference		Description	BEC Part Number
S1	Switch, Toggle DPST	Carling #216-62	465,100
S6	Switch, Toggle DPST	AH & H 81027AZ	465,101
T1	Oscillator Coil	Special	074,024
T7	Transformer, Power	Stancor PC 8401	446,007
TS-1	Terminal Shield		074,022
V1	Tube	6C4	526,6C4
V2	Tube	6AU6	526,6AU6
V3	Tube	6AU6	526,6AU6
V4	Tube	6X4	526,6X4
V5	Tube	OA2	526,OA2



SCHEMATIC DIAGRAM

CAPACITANCE BRIDGE

MODEL 74C-521

(TEST FREQUENCY: ~~1000~~ 20 KC)

Boonton *ELECTRONICS* Corp.

MORRIS PLAINS, N.J.

CAPACITANCE IN pf(µµf) UNLESS NOTED
RESISTANCE IN OHMS (K=1,000)
⏚ PANEL GROUND
✱ BRIDGE SHIELD [SEE S5b FOR CONNECTIONS]
◉ PANEL CONTROL
✱✱ 0 TO 10,000 pf IN 1,000 pf STEPS

~~830,002H~~

830,113A